An investigation on a quantum communication phenomenon between sub-atomic properties of substances by Quantum eraser pattern quantification

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Abstract

The proposed novel idea is concerned with the investigation on a probability of sub-atomic quantum communication between the chemical substances by use of "interferometric Quantum eraser" pattern analysis, which would be the first step towards the further comprehensive study on a similar natural communications between the medications and diseased organic tissues. The hypothesis is based on the idea that, sub-atomic particles like photons attempt to access or gain complementary information causing their "wave-particle duality" shifting which is used to observe their time-sequenced activities. Such information would probably be provided by sub-atomic quantum communication action demonstrated between the substances in a chemical reaction. Similarly, the medications may have curing effects on a diseased organic tissue after such "natural" communication, by which a complementary information is transferred from the sub-atomic properties of chemical substance to the diseased organic tissue at same level for the treatment.

Keywords : chemical reactions, drug design, pattern analysis, quantum technology, light physics, laser interferometry

1 Introduction

Quantum technology is very fundamental and promising area of contemporary sciences including the sub-branches such as quantum optics, quantum mechanics, quantum computing, etc. As is described in several sources [1][4] the term Quantum refers to a description as the minimum amount of physical property involved in an interaction. In quantum optics this is most often a single photon or in other cases any sub-atomic particle such as neutron, proton, electron or a single atom itself. One of the distinguished characteristics of quantum mechanics is that [2], "In classical mechanics, when something happens it happens for a reason, but in quantum mechanics world, the events can occur without any reason ". In quantum experiments the particles exhibit very interesting behaviours such as existing in two different places simultaneously with 50% possibilities for each (superposition), communicate with each other whatever distant they are (entangling), and pass through the barrier without any resistant (quantum tunnelling). This proposed work is mainly concerned with an introduction of specific type of "natural" quantum communication (other than commonly described), where sub-atomic particles are exchanged or interacted between the two substances, such as between the transmitter (e.g. medication) and receiver (e.g. cellular tissue). The idea has been inspired by a traditional communication phenomenon in our classical World domain in which we exchange, transmit or receive sub atomic-particles (electrons, photons, etc.) for information transmission as we call it "communication". But we do not call the same phenomenon as "communication" when substances themselves do the same thing. We rather call the receiver substance a completely a new product when it receives even a single atom or electron (e.g. $CO + O = CO_3$). According to Quantum mechanical principles, the sub-atomic particles or any particle like photons, electrons or even molecules exhibit wave-particle duality actions. But for macroscopic particles like molecules because of their very short wavelengths, their wave properties can not be detected [14]. In regards to this phenomenon, our hypothesis is also based on the idea that the sub-atomic particles of substances those involved in a chemical reaction may attempt to access or gain complementary information for "wave-particle duality" actions amongst the natural quantum communication exchanges between those substances. Similarly, the medications may become effective on a diseased cellular tissue by a such communication, by which a complementary information is transferred from the sub-atomic properties of substance to the diseased organic tissue at same level for its healing.

Within this work, a proposed natural communication action between the two separate substance domains is investigated by the experiments that made by utilizing a well-known interferometer (Mach-Zehnder). The tests performed are based on quantum physical principles so that a CW laser light at 532nm wavelength (simulating a single photon) is emitted along the interferometer and the light beam is then splitted by two paths (called arms) by interferometer's optics, then join together at the end producing an interference pattern (exhibiting the wave property of photons). The pattern is stimulated by interaction between the interferometer's lower or upper arms and a substance under investigation is located along the path of first arm (e.g. sample in a glass chamber). In experimental setup, the chamber is to generate a test medium whose refractive index differs from the second arm. Our hypothesis proposes that the time-sequence variations of refractive indices are caused by sub-atomic interaction between the substance and liquid in the chamber. And such interaction between the two substances may correspond to a natural quantum communication, and stimulates the interference pattern. Time-sequenced changes on the interference pattern is then quantized by use of video image analysis algorithm called *Optical flow* [3] in a three dimensional (x,y,t) dynamic form. Optical flow is one of basic image analysis techniques utilized to track single or group of objects on a video sequences by use of vectoral displacements of their image pixels. In our case the vectoral displacements on the interferometric pattern of the quantum eraser set are quantised by their total-flow-magnitudes and V_y directional flow calculations. Since the pattern fringes are symmetrical, only one directional (V_y : Vertical) flow analysis would be sufficient. Meanwhile the total magnitude refers the sum of all absolute values of the vectoral motions.

One of the most similar past works was introduced by McIntyre and Bishop in 2012 [6] as they analysed the interferometric fringes of a single image to extract phase shift instead of time-sequence dynamic video data as we investigate. Their method mainly aimed to determine gas/plasma flow parameters by use of interferometer in association with a standalone software specifically developed (in Java) for this purpose.
Our proposed idea to investigate low level communication between the test substance and target domain was already proven by atomic exchange level [17] presented by an earlier work, which corresponds to a chemical (proof-of-concept) verification of our proposed idea. In our experiments, the quantum eraser interferometric set (Figure 1) exhibits also an amplification function of atomic exchange level and display its intensities by interferometric pattern (Figure 2) changes in a time domain. The quantitative output of video time series include video image pixels optical flow values (total, x and y directions) whose graphs are displayed in Figure 3 and 4.

2 Methods and materials

2.1 Test Materials used

For the interferometric tests, 0.5 gr Sodium Hydroxide (NaOH) is used for the reaction with 3.8cc Hydro Chloric Acid (HCl) and 0.5 gr Boron Oxide (B_2O_3) is used for the reaction with 3.8cc water (H_2O) in a Quartz test chamber whose interior volume is 4.3cc. The details of the tests are already described in Chapter 3.2.
In the second group of tests, medical tablet substance Benecel^{TM} is used for verification of low level communication. Benecel^{TM} Hydroxy Propyl Methyl Cellulose (HPMC: $C_{56}H_{108}O_{30}$) tablet set at two different grades (K4M and K100M) are used with Acetone (C_3H_6O) as a target domain for the low level communication.

2.2 Mach-Zehnder Interferometer (simulated Quantum eraser set)

The simulated Quantum Eraser (*QE*) Set (also called Mach-Zehnder interferometer) is used in our experiments which uses a laser light source instead of single photon source. The interferometric pattern generation process is summarized in Figure 1, as two overlapping coherent CW laser beams (at λ=532nm) are interacted at the point of beam splitter-2. As this beam splitter erases the path information of photons emitted by laser source earlier following the arm 1 and 2, after the beam splitter-2 "complementary" interference wave pattern appears on display 1 and 2. In quantum physics this phenomenon is described as: the photons behave like a wave instead of particles since their path information (which path they follow) can not be known as is erased [8] by the beam splitter-2. If the photons would not behave like a wave, following the both path with 50% possibilities for each, then we would have no chance to exploit photons to detect any communication between the substances in the sample chamber since such observation and measurements would only be possible in a probability (wave) domain as photons' particle domain does not produce and interferometric pattern. Hence within this wave form there is a high possibility of another series of interaction between the photonic information (for both arms) and substances' communication in the sample chamber. In quantum physics such non-classical interactions are quite common, as the sub-atomic particles like photons are capable of entangling with even the camera sensors to access any complementary information they need to behave like a particle (to avoid possibilities other than 100%). The popular quantum physics "particle-wave duality" ideas would be further interpreted that, a wave characteristics provides photons an enormous capability to travel in time [9], entangle with any atom or sub-atomic particle at any far distance [10] or behave like existing in two different locations simultaneously [4]. This is because in a probability (wave) domain, the photons do not appear with 100% solid (particle) identity as would be restriction by a certain time and location, but rather have flexibility to exhibit many non-classical capabilities which would be exploited by the contemporary research in many branches. In our experiments, the wave form of photons are exploited in the quantum eraser set as they more likely to detect and interact with "information exchange traffic" in probability domain. This is possibly because photons attempt to access or gain complementary information amongst the communication exchanges between the substances in the sample chamber to upgrade to a particle domain. Wave-particle duality have already been studied by several earlier researchers [11].

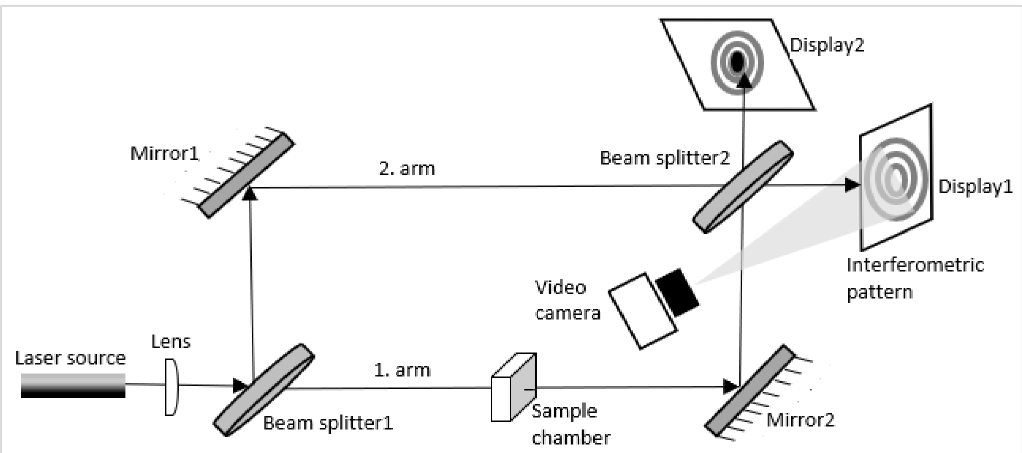


Figure 1. Mach-Zehnder interferometer (QE) setup with video recording facility for time-sequence pattern analysis. The pattern fringes shown on Display 1 and 2 are in complementary form due to quantum eraser principles.

As seen in Figure 1, the time-sequence changes in sample chamber are reflected by pattern fringes on Display 1 and 2. And at specific time t_i, two-dimensional (x, y plane) interferometer pattern intensity formula would be described as [7] in Formula (1)

$$g(x, y) = a(x, y) + b(x, y) \cos[2\pi(\omega 0x + \nu 0y) + Ø(x, y)] \qquad (1)$$

where; *Ø(x, y)* : the phase difference between the two overlapping beam
a(x, y) : background intensity
b(x, y) : variability in the visibility of fringes
ω0 and ν0 : the fringe frequencies in the x and y directions respectively.

2.3 Video Imaging utility

The system consists of high resolution *CCD* (*1296x964 pixel*, *Flir® USB*) camera, its video acquisition utility called *PointGrey Fly Capture2* (data storage in .avi format) and specific utility for video analysis has been developed by using Optical Flow (*Lucas-Kanade*) algorithm described in Section 2.4. The system is capable of high speed image acquisition as 18 frames/sec with 16-bit pixel depth.

2.4 Optical flow method

The optical flow (*OFL*) algorithm can be defined by its general formula (2) :

$$I'(x, y, t) = I(x + \Delta x, y + \Delta y, t + \Delta t) \qquad (2)$$

The formula 2 would be described as follows : For successive video frames (I' and I) each 3D voxel (2D pixel + t) at location *(x,y,t)* with intensity I (x,y,t) will be moved by Δx, Δy, and Δt between the two video frames. We adopted well-known *Lucas-Kanade* method for the optical flow [5]. This method has two basic assumptions which are reasonably valid in our application: brightness is constant over motion and the motion is constant in a small neighbourhood. The optical flow values (Δx, Δy) are exhibited in Figure 2, y-axis. In the algorithm the noise threshold was selected as 0.21 and the video image data were converted to grey-scale. Since the interferometric pattern fringes (Figure 1) have symmetrical characteristics, only vertical directional optical flow vectors at top semi-circle have been counted. The *OFL* algorithm is fast enough to follow the video sequence (in .avi format) at the same speed for vectoral calculations, hence it can operate in real-time. The pseudo code of pattern analyser software is shown as script below :

```
// program_opticalFlow_for_Quantum_EraserPattern_analyser//
    read_Video (file.avi);
        define_parameters (noiseThreshold, region_of_interest, decimal_factor, scale_factor, time)
            while_loop_Start
                read_Frame (i);
                    convert_to_grayLevel ;
            estimate_opticalFlow (save ; display [total_magnitude, direction_Vy, time] );
             delete_Frame (i);
          while_loop_Ends
         end
```

3 Results and discussion

3.1 Photons' wave-particle duality

In quantum physics wave-particle duality was earlier introduced comprehensively by Wootters-Zurek [13] in 1979. And the formulation of wave-particle duality was introduced by Einstein (1905) and then extended by Louis de Broglie (1924). According to the expression of wave-particle duality, photon (particle) energy *E* can be stated [15] as ;

$$E_{photon} = \frac{hc}{\lambda} = cp \qquad (3)$$

Here;
h : Planck's constant (6.626 x 10^{-34} m^2 kg/s)
c : speed of light
λ : wavelength of light
p : magnitude of momentum

The photon's wave-particle duality would be further explained by Schrodinger's equations by a harmonic wave function ψ [15] ;
Even though the photons have no mass, they carry momentum which is related to photon's energy as in Formula 3.

$$\psi(x, t) = Ae^{i(kx - \omega t)} \qquad (4)$$

Where ; x : particle position at time t
A : amplitude
k : wave vector
ω : angular frequency
i : 1,2,3 (used in the context of Hamilton-Jacobi equation)

In the experiments, photonic "wave-particle" duality is associated with the two-way characteristics of the interferometer in which the photonic interference displays fringe pattern (Figure 2) that refers to wave aspects, whereas the which-way information of photons refers to their particle form [12]. According the quantum optical principles when laser beam is divided by a beam splitter 1 (Figure 1) and joint together by Beam splitter 2 (Figure 1), then photons exhibit wave characteristics as far as the divided photons which-way information is unknown [4]. There are many circumstances where the which-way information is provided to specify which arm of the interferometer is really chosen by the photons to follow. Our hypothesis proposes that the which-way information may also be accessed or extracted from sub-atomic communications action between the test substances whose chemical reaction takes place in the sample chamber, where the photons pass through via a laser beam. This physical phenomenon can also be described as refractive index change in the sample chamber (in classical light physics), as such change causes the phase difference between the first and second arms of the interferometer. But according to earlier interferometric experiments [16] any change in refraction index would normally cause fringes-cycling based pattern changes [16], whereas in our experiments image pixel displacements on the interferometric pattern are possibly caused by local particle-wave duality actions of photons passing through the chemical reaction in test tube. The idea is based on the role of refraction index changes causing the wave-particle shift of the laser beam, exhibited partially by QE pattern in a time-sequence. In our experiment set, such wave-particle behavioural shifts are activated by the sample chamber in which a chemical reaction is demonstrated. This has a similarity with wave-particle triggering of the laser light in QE by a polariser located on one path which provides a path information continuously rather than partially-time-sequenced one by a chemical reaction chamber.

3.2 Verification test 1. High and low communication observation via atomic exchange in chemical reaction

Two categories of the observation have been made via chemical reactions tested in a sample chamber of Quantum Eraser set. The type of chemical reaction tests have been decided as they exhibit distinct atomic exchange numbers (2 against 9) during the reactions. For the tests, 0.5 gr Sodium Hydroxide (NaOH) is used for the reaction with 3.8cc Hydro Chloric Acid (HCl) and 0.5 gr Boron Oxide (B_2O_3) is used for the reaction with 3.8cc water (H_2O) in a Quartz test chamber whose interior volume is 4.3cc. The chemical reaction with NaOH represents the first (low level) category of sub-atomic communication where only 2 atoms are exchanged between NaOH and water, whereas in the second (high-level) communication test, Boron Oxide and water are in a reaction by exchanging 9 atoms [17] as below formulas :

NaOH + HCL = NaCl + H_2O ; (Na, Cl => 2 atom exchange reaction)
B_2O_3 + 3(H_2O) = 2(H_3BO_3) ; (6(H), 3(O) => 9 atom exchange reaction)

The video (.avi) sequences of those two separate reactions last about 6 and 15 minute periods respectively (Figure 2). As shown in the figure, only first top-half of the quantum eraser pattern is recorded and then quantised since the pattern has a symmetric shape and the numerical properties of each half are very identical.
The experiments shows that low-level communication (2 atom exchange) whose QE major pattern optical flow activity lasting about 6 minutes is shorter than the high-level (9 atom exchange) communication's QE pattern optical flow activity which lasts about 15 minutes (Figure 2). Their optical flow intensities also differ as shown in Figure 3 and Figure 4.

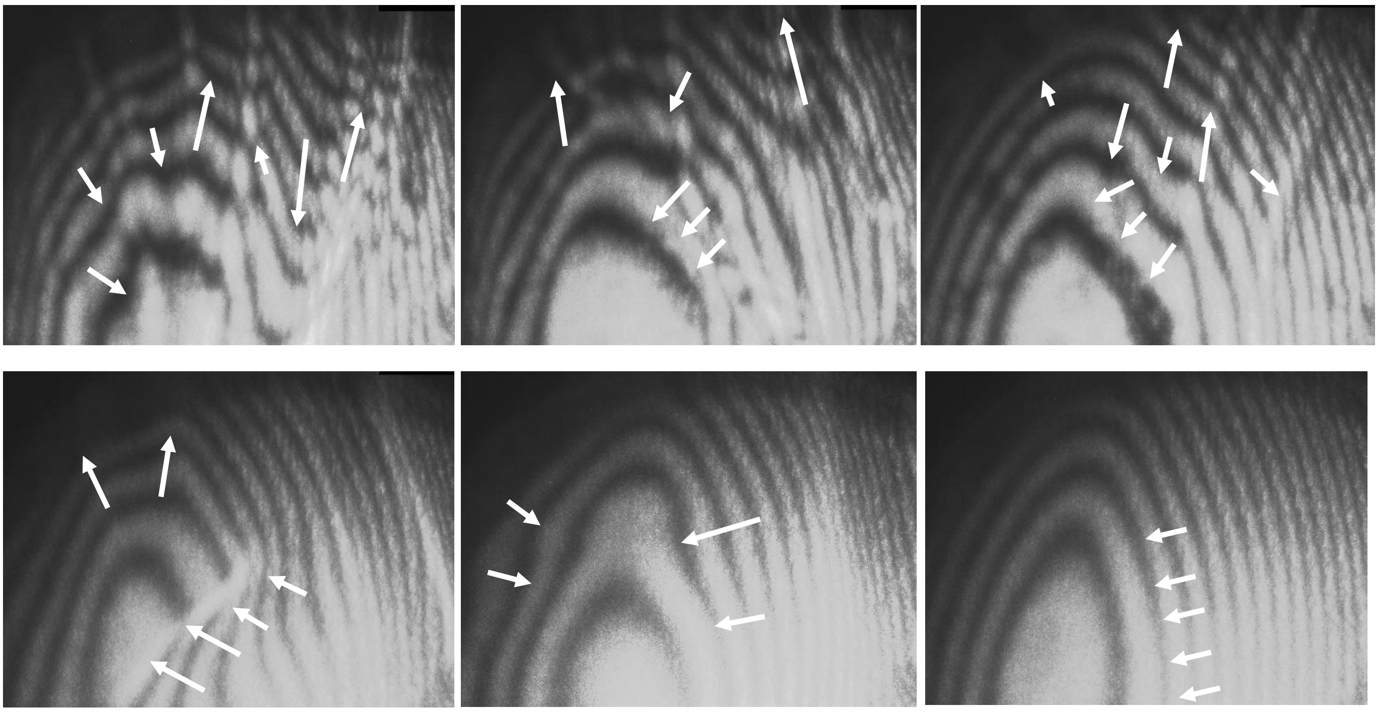
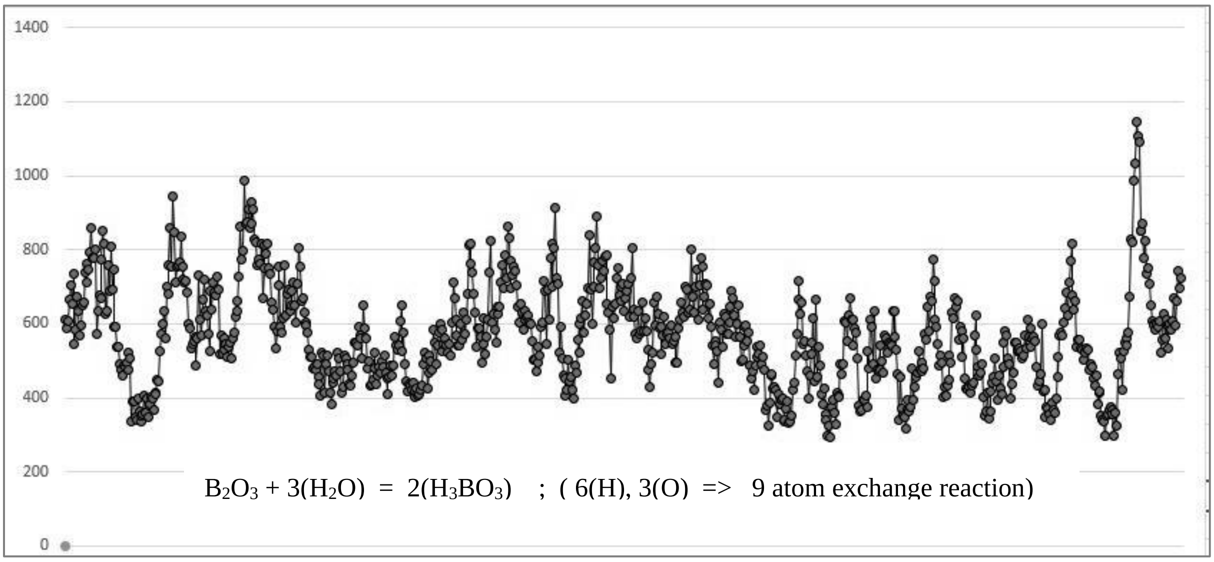


Figure 2. Samples of Quantum eraser interferometric patterns. Each one displays (snapshot of video recordings) the related atomic exchange communication activity in its specific chemical reaction demonstrated in the test chamber. High level communication examples (top images) exhibit higher level QE pattern changes than low level (bottom images) communication ones according to the optical flow results in Figure 3 and 4. The vectoral arrows indicate the major image pixel displacements caused by local particle-wave duality actions of photons passing through the chemical reaction in test tube..



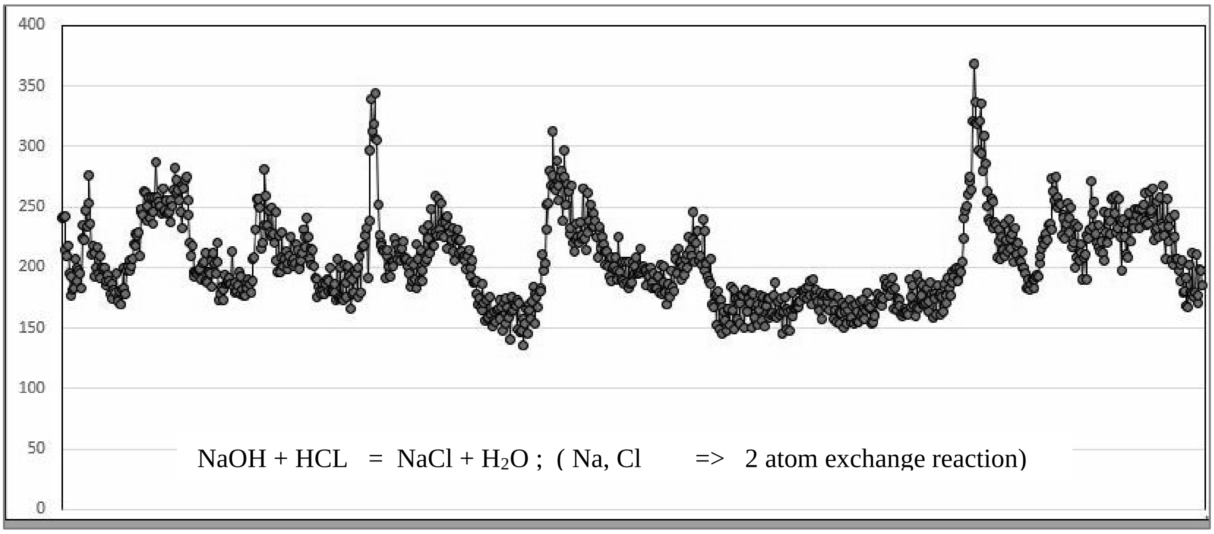
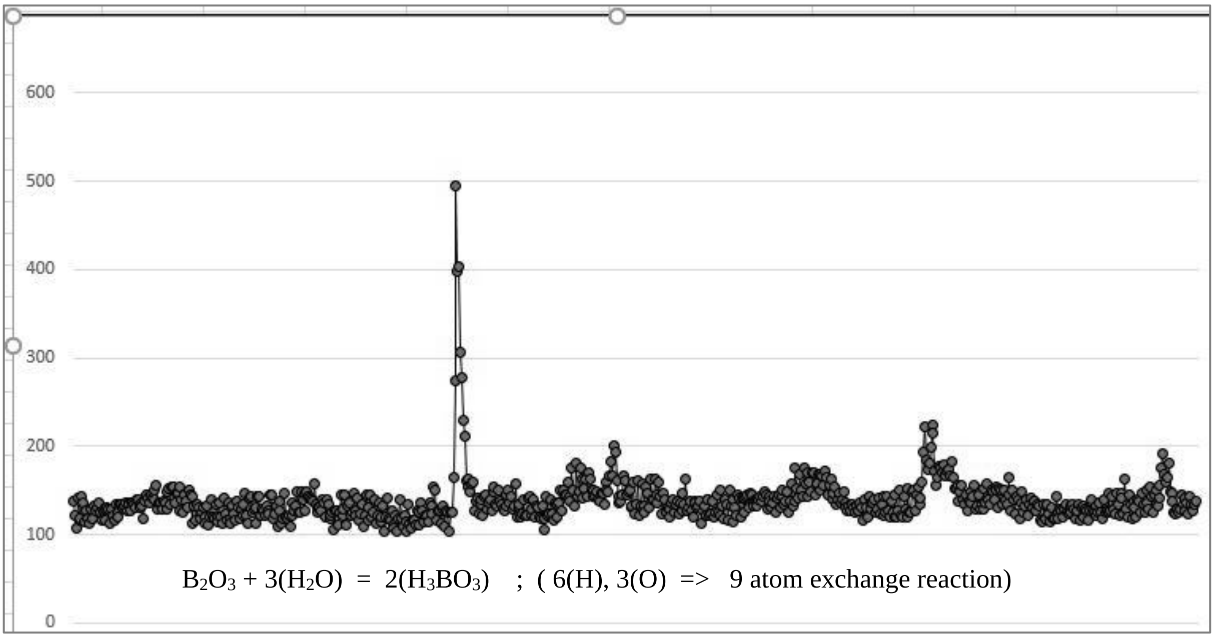


Figure 3. **First phase of recording** : Optical flow values of time-sequence changes on interferometric pattern fringes during the substances' natural quantum communication. First graph (top) belongs to reaction of Boron Oxide & Water showing a high communication level by higher optical flows whose values change between 300 – 1000 ; The second graph ((bottom) exhibits a low communication level of "Sodium Hydroxide & Hydrochloric acid" whose optical flow ranges mainly varies between 150 – 300 (axes: y =optical flow, x = time)



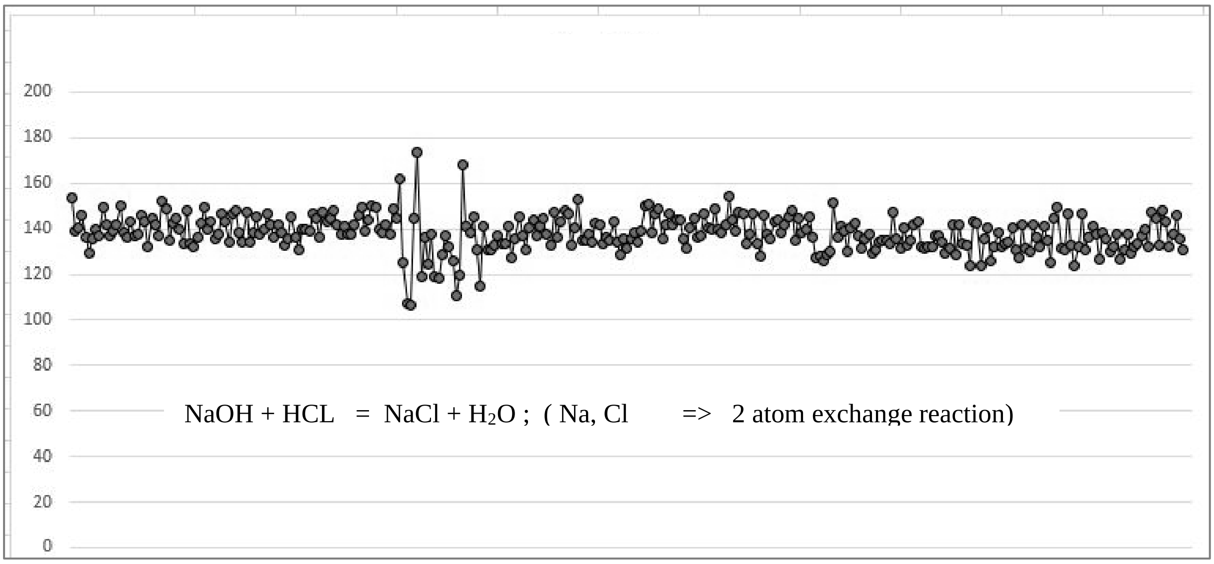


Figure 4. **last phase of recording** : Optical flow values of time-sequence changes on interferometric pattern fringes. First graph (top) belongs to reaction of "Boron Oxide & water" showing a high communication level by higher optical flows whose values change approximately between 100-200 ; The second graph ((bottom) exhibits a low communication level of "Sodium Hydroxide & Hydrochloric acid" whose optical flow ranges mainly varies between 120-160 (axes : y = optical flow, x = time)

3.3 Verification test 2: Benecel^{TM} tablet and Acetone communication observation

For a low level communication activity observation test between medical tablet substance and target domain, Benecel^{TM} Hydroxy Propyl Methyl Cellulose (HPMC: $C_{56}H_{108}O_{30}$) tablet set at two different grades (K4M and K100M) are used which have very identical parameters as seen in Table 1. The communication target domain is Acetone (C_3H_6O).

Table I. Benecel^{TM} (HPMC) tablet sets specifications for the grades K4M and K100M (average values of tablet sets)

K4M				**K100M**			
Tablet weight (mg)	Tablet diameter (mm)	Tablet thickness (mm)	Tablet density (mg/mm^3)	Tablet weight (mg)	Tablet diameter (mm)	Tablet thickness (mm)	Tablet density (mg/mm^3)
163	**8.04**	**3.30**	**0.98**	**161**	**8.06**	**3.26**	**0.9**
Weight average molecular weight = 400,000				Weight average molecular weight = 1,000,000			

3.3.1 Test results

The test results show that the higher tablet grade levels lead to larger optical flow values of quantum eraser set's interferometric pattern changes (Table 2 and Figure 5). This would prove that the tablet grade level is inline with quantum communication intensity level between tablets and target domain . In the test "standard deviation" of the optical flow values is taken as activity criteria which is 65 and 170 for K4M and K100M tablets respectively whose configurations are displayed in Figure 5.

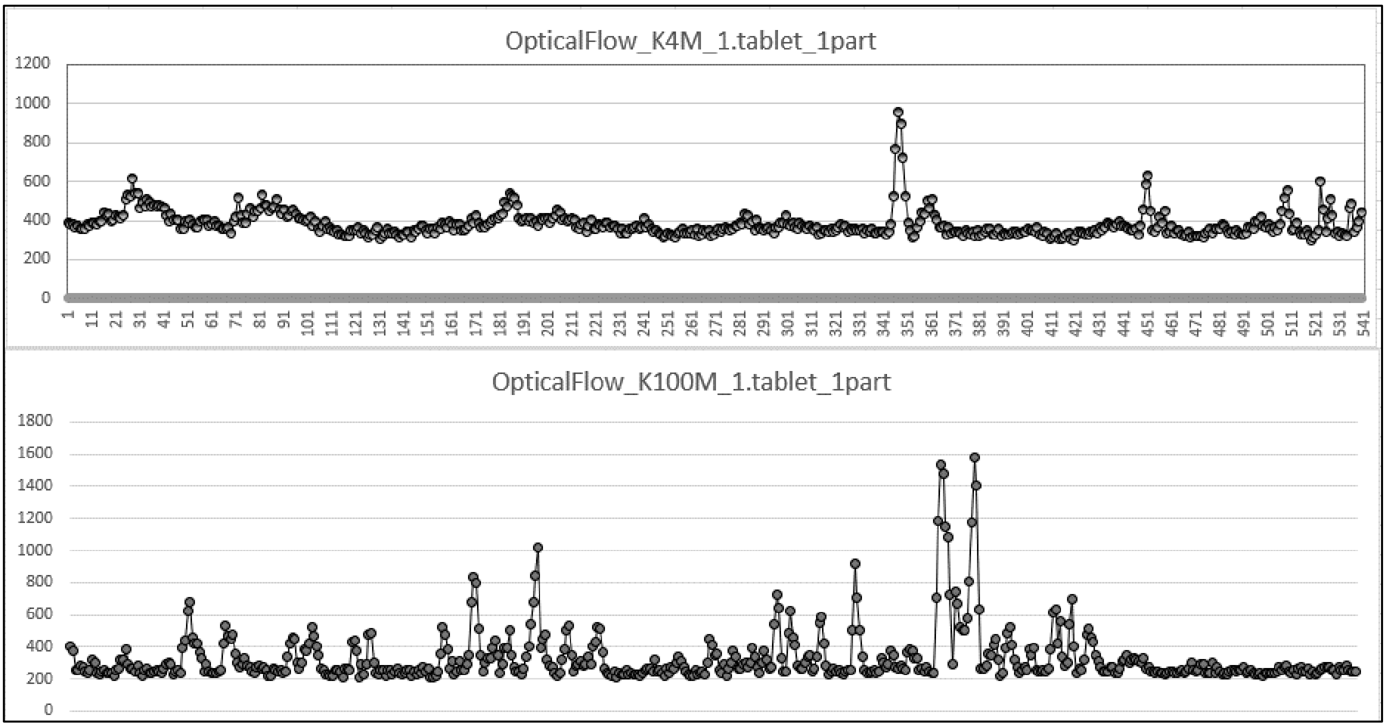


Figure 5. The test results show that the higher tablet grade level (K100M) lead to larger optical flow values (in the range of 200-1600 optical flow values) of quantum eraser set's interferometric pattern changes whose values are extracted from the interferometric pattern video image. The *X* axis refers to 5-6 minutes time period.

Table II. Optical flow Activity results of Benecel[TM] and Acetone interaction (refers to low level quantum communication) in QE test chamber (the last column indicates that standard deviation of optical flow values is inline with the tablet grade level)

Test No	**K4M** (standard deviation)	**K100M** (standard deviation)	**Optical flow level verified by grade**
1	14	27	√
2	65	170	√
3	24	27	√
4	94	24	X
5	15	34	√
6	42	44	√

Conclusion

Within this work an attempt has been made to bring a lower level (non-classical) description to physical interferometric phenomenon where in classical description a single arm of interferometer interact with a sample domain (e.g. chamber) to cause a phase shift by the refractive index changes in the test chamber during the sample analysis. Whereas from the quantum concept's point of view, the same event could be described as local wave-particle shifts of photons exhibited in different parts of interferometric pattern as they pass through a test chamber, in which the chemical reactions demonstrate different level of atomic communications. By exploiting such wave-particle duality shift phenomenon, we have tried to prove the hypothesis of "natural quantum communication" in association with our optical and computer vision facilities such as interferometric quantum eraser kit, video recording and data analysis utilities equipped with image analysis (e.g. optical flow, etc.) methods. The results showed that different level of atomic or sub-atomic communication would be observable on a time-sequences domain by use of Quantum eraser set in association with video image acquisition and analysis techniques. The results are promising for further experiments in which the similar low level natural communication would be observable between the different medication substances (e.g. active ingredients) and diseased biological tissues to prove the idea that diseased biological tissue may be intervened and cured by such natural quantum communication.

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